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WATERTOWN ARSENAL LABORATORIES

SPOTTING ROUND PROJECTILES: FEASIBILITY STUDY ON DEVELOPMENT

TECHNICAL REPORT NO. WAL TR 160.73/1

BY

F. A. BROUILLETTE

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JANUARY 1960

O.O. PROJECT: TB3-1224, VULNERABILITY OF TANKS - CONCEPT STUDIES HEAVY INFANTRY ASSAULT WEAPON
D/A PROJECT: 503-04-004

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Spotting charges, projectiles

Projectiles, development

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SPOTTING ROUND PROJECTILES, FEASIBILITY STUDY ON DEVELOPMENT.

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By

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12 29

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WATERTOWN ARSENAL
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WATERTOWN ARSENAL LABORATORIES

TITLE

SPOTTING ROUND PROJECTILES: FEASIBILITY STUDY ON DEVELOPMENT

ABSTRACT

Exploratory ballistics impact tests have been made in which 0.510-inch-diameter scale model projectiles were fired at steel armor material at zero and 45 degrees obliquity. The projectiles were prepared from several types of metals, and also with a variety of filler materials included in their nose sections.

Observations of the terminal impact effect has been accomplished by comparing the zone of impact upon the target and the fragment dispersion upon a paper target completely surrounding the armor material.

Preliminary ballistic results have indicated that pronounced fracture and dispersion differences occur within the variety of projectile materials, as well as in the nose fillers. Initial tests have also established that as the angle of projectile attack is increased the zone of both the projectile and filler material dispersion progressively decreases, and at low velocities soft metals are more effective. However, the amount of material deposited on the target was relatively small and not considered satisfactory for spotting round purposes. Therefore, it was concluded that additional tests be made using different designs with the aim of selecting one which would be capable of depositing a greater quantity of material, particularly on targets positioned at obliquities.

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Date- 4 Feb 60
WAL Board of Review
Chairman- WFW

INTRODUCTION

The idea of a spotting round projectile is not new; there are many historic records concerning the effectiveness of spotting arrows, illuminating shells, parachute flares, and the like. The need for a spotting round is very important in many present day battle situations, because it would conserve the costly major projectiles until the hit probability was practically assured, and it would also reduce the chance of pre-disclosing the area of attack or the position of concealment.

This series of ballistic evaluation tests has been conducted with the aim of selecting for further study one or more projectile materials which would leave a residual deposit on normal or oblique armor material that would be easily detectable by either visual or instrumental means.

In planning these tests, it was considered that any such projectile material, in order to disperse readily on impact, must necessarily be of a substance already in suspension as a filler material carried in a projectile nose cavity, or be a solid material which would attain partially but instantaneously, a liquid state, by melting on impact. It was further considered, that for daylight spotting, the desired material must possess a high degree of reflectiveness, or for night spotting, a high degree of luminosity.

To more easily attain the desired objective each projectile containing a filler material was machined with a circular cutting edge at its forward end which was designed to mark the armor. The effect of this cutting edge and its possible merit for further testing is discussed in this report.

TEST MATERIALS, EQUIPMENT AND PROCEDURES

Finished Test Projectiles

The finished test projectiles, 0.510 inch in diameter, were of two types: solid and nose-filled. Their complete dimensions, with drawings, are shown in Figure 1 and their weights in Table I.

The solid projectiles had cylindrical bodies, flat bases, spherical noses, and were machined from aluminum, copper, lead, and titanium.

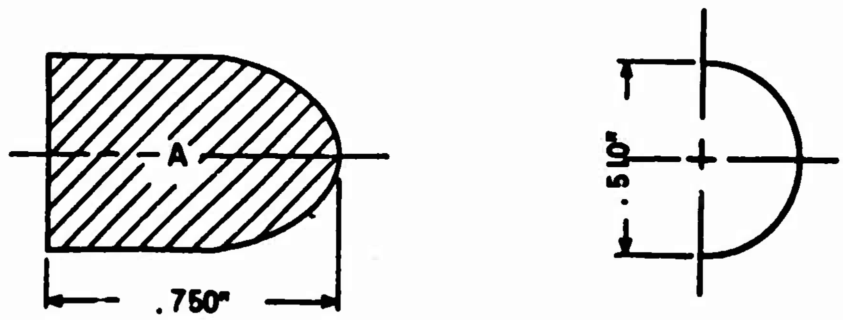
The nose-filled type were similar to the solid ones in body and base shape, varying only at their nose sections, into which cylindrical cavities were drilled, as shown in "B" of Figure 1.

The finished nose-filled projectiles, without filler material, each weighed approximately 188 grains. Each projectile was filled with one of the following materials: asphalt, white lead, chrome yellow paint, and Wood's Metal, and then refinished, leaving the noses blunt as shown in "B" of Figure 1.

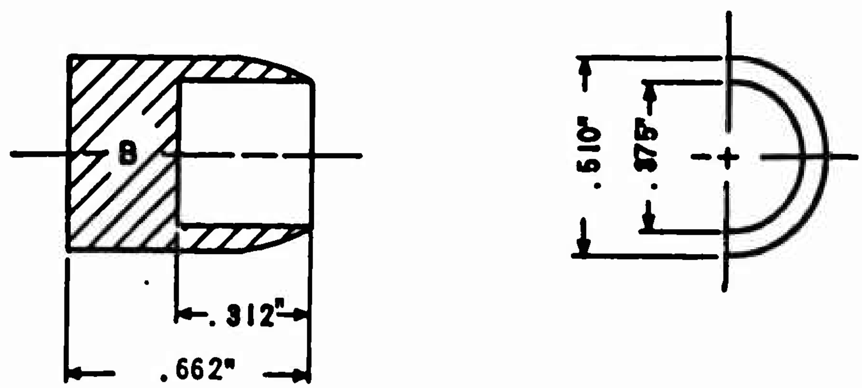
TABLE I

BALLISTIC RESULTS

Projectile Material	Weight (Grains)	Propellant Type	Charge (Grains)	Velocity (Ft-Sec)
Projectiles Fired at 0° Impact				
Aluminum	95	IMR 4064	75	2270
Copper	303			1800
Lead	389			1825
Titanium	153			2400
White Lead in Steel	232			1780
Chrome Yellow Paint in Steel	209			2060
Wood's Metal in Steel	259			1815
Asphalt in Steel	203	IMR 4064	75	1905
Projectiles Fired at 45° Impact				
Aluminum	95	IMR 4064	75	2320
Copper	303			1860
Lead	389			1810
Titanium	153			2075
Chrome Yellow Paint in Steel	209			1970
Wood's Metal in Steel	259			1685
Asphalt in Steel	203	IMR 4064	75	1915



A. SCALE MODEL MONOBLOC PROJECTILE



B. NOSE-FILLED SCALE MODEL PROJECTILE

FIGURE I

Ballistic Firing Equipment

The projectiles were fired from a standard caliber 0.50 machine gun barrel having one turn in 15 inches, and equipped with a Frankford Arsenal-type breech action.

The standard caliber 0.50 M2 cartridge case was used and the propellant was a single base solid-propellant type IMR 4064 which is normally used in caliber 0.30 cartridge cases.

Velocity Measuring Equipment

The velocity recording equipment was a Potter 1.6 megacycle counter chronograph actuated by a Watertown Arsenal Laboratories Triggering Device.

The two actuators (triggering grids) were mounted at 5 feet from the muzzle of the gun tube to start the counter chronograph and 7.5 feet from the muzzle of the gun to stop the counter chronograph. The impact armor was located at 10 feet from the muzzle of the gun tube and 3.75 feet from the midpoint of the two actuators; Figure 2 shows the complete arrangement.

The Target Setup

The target material, for each round fired at both zero and 45 degrees obliquity, was a 3/4" rolled homogeneous armor plate, heat-treated to a hardness of 330 BHN, mounted and secured in a holding device, and surrounded by a cylindrical target made of kraft paper which was stapled to the inside of a sturdy cardboard cylinder.

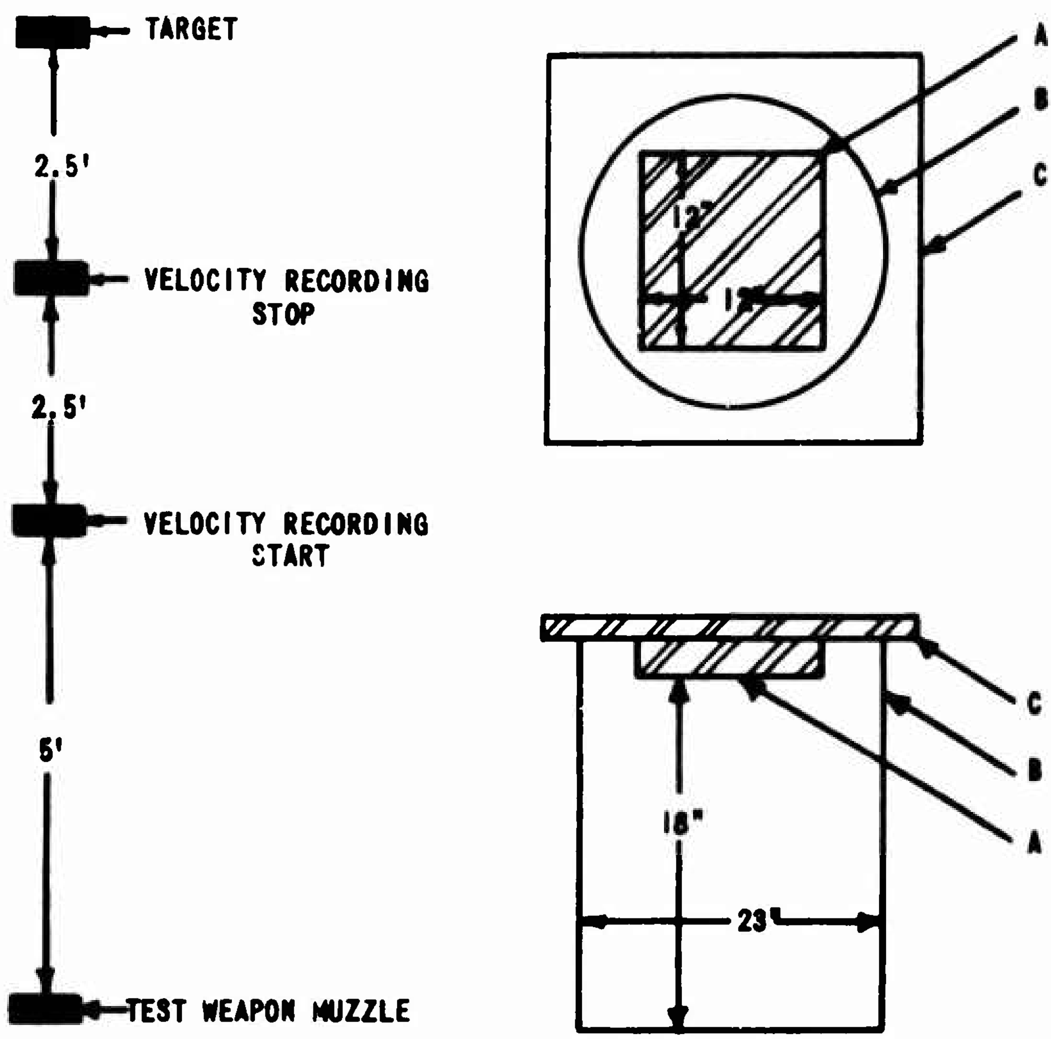
This cylindrical target, at both zero and 45 degrees obliquity, was positioned around the armor and secured with its forward end flush against the plate holder, thus establishing a constant radius of 11.5 inches from the point of impact to the circumferential surface of the paper target material. To allow free passage of the projectiles at 45 degrees obliquity, a section 8 inches long and 2 inches wide was removed from the top of the cylindrical target. The complete setup, with front and side views at zero degrees obliquity, is shown in Figure 2.

OBSERVATIONS OF MATERIAL DEPOSITS UPON THE ARMOR AT ZERO DEGREES OBLIQUITY

Deposits of Solid Metallic Projectile Materials

Impacts upon the armor of the spherical-nose solid projectiles made partial penetrations in the form of craters which were partly coated with metal, and which varied in diameter according to depth.

Craters made by the copper and titanium projectiles were deep and well-formed, showing heavy deposits of bright metal around the edges. However, there was no deposit visible at the center section of either.



A - ARMOR IMPACT PLATE
B - CYLINDRICAL TARGET
C - ARMOR PLATE HOLDER

DIAGRAM SHOWING ARRANGEMENT OF VELOCITY RECORDING AND TARGET APPARATUS

FIGURE 2

The crater made by the aluminum projectile was shallow, and its center, like those of the copper and titanium craters, evidenced no deposit of metal, but a brilliant and relatively large encircling deposit of vaporized aluminum distinguished it from the others.

The lead crater, slightly deeper than the aluminum one, was surrounded by a thin film of vaporized lead which was dull to the extent that it was barely visible.

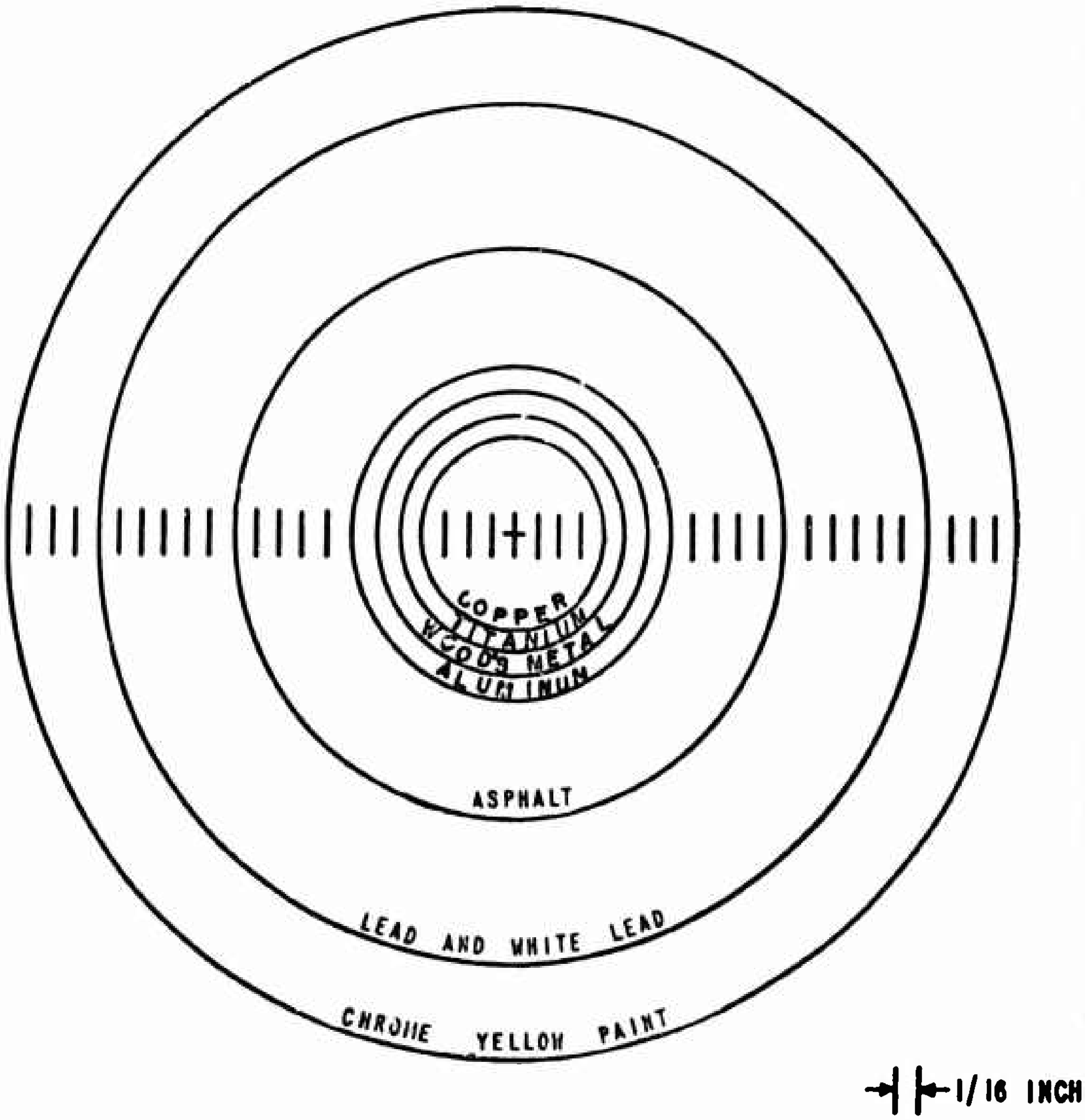
Radial streaks of vaporized metal, varying in length and depth, extended in all directions from the deposits of metal around each of the four craters. These radial streaks were short, narrow, well-defined, and uniformly spaced around the copper and titanium craters, but longer, heavier, less uniform, and not so clearly defined around the lead and aluminum ones. These differences appeared to be attributable to the greater lateral dispersion from the shallow craters of aluminum and lead as well as the lower melting properties of these metals (Figure 3).

Deposits of Metallic and Nonmetallic Filler Materials

On impact the colored filler materials carried in the nose cavities of the mild steel projectiles dispersed liberally and extensively around the points of impact and also over the entire surface of the armor in uniform distribution. A considerable amount of the deposited material was in the form of scattered beads and irregularly shaped particles. This was particularly evident on the plates impacted by the projectiles filled with either chrome yellow paint or white lead.

The dispersion pattern of the asphalt filler material showed a deep-hued black circular deposit surrounding the point of impact, from which plainly visible splash streaks extended to the four edges of the armor, fading progressively with increase in length.

The Wood's Metal dispersion was unique, showing a considerable amount of bright metal deposited evenly within a gouged-out annular area which surrounded and isolated the point of impact in moat-like fashion. Similarly shaped areas surrounded the points of impact of the other filler materials (asphalt, chrome yellow paint and white lead), but none evidenced the depth nor the extent of deformation that characterized the Wood's Metal area. (The formation of these annular areas is described in "Results and Discussion," p. 13.) Also, the Wood's Metal point of impact, unlike that of the other filler materials, showed a smooth, evenly depressed crater of appreciable depth which would hardly suggest creation by force of impact. This phenomenon, as well as the extensive gouged-out area described above, probably resulted from the sudden impact upon the armor of a contained mass of Wood's Metal, microsecondly converted into a fluid state, exerting dynamic pressure upon the armor. Peculiarly, the outer circumference of the Wood's Metal annular area was the line of limitation for the radial dispersion of that metal on the armor. The comparative diameters of the circular deposits of the filler materials are shown in Figure 3.



AREAS SHOWING RADIAL CONCENTRATIONS OF RESIDUAL DEPOSITS RESULTING FROM PROJECTILES IMPACTED UPON ARMOR MATERIALS AT 0° OBLIQUITY

FIGURE 3

OBSERVATIONS OF MATERIALS DISPERSION UPON THE ARMOR AT 45 DEGREES OBLIQUITY

Dispersions upon the armor, resulting from the impacts of solid and nose-filled projectiles at 45 degrees obliquity, were confined to the lower section of the armor in cone-shaped zones which varied in angular measurement, as shown in Figure 4. Each of these dispersions had its origin at the point of impact where material was most heavily deposited.

A wide difference in the character of deposits in the various zones was noted. In some the coatings of material were thin, in others they were heavy with deep coloration. Radial streaks, particularly, showed a wide variance, being considerably longer, heavier, and deeper-hued in the non-metallic materials.

The copper projectile left a bright half-moon-shaped coating of metal at the point of impact, which widened into a thin and barely visible film of vaporized copper with short radial streaks.

The lead zone of dispersion, also wide, was thinly spread, had long radial streaks, but was dull in color.

The aluminum and titanium zones were small in area, but that section immediately below the point of impact in each showed a deposit of shining vaporized metal, particularly brilliant in the aluminum zone.

The asphalt and chrome yellow paint zones displayed clear and distinctly outlined marks of dispersion, but asphalt because of its dark color against the drab background of the steel armor, did not stand out so prominently. The radial streaks in the chrome yellow paint pattern showed a marked increase in coloration as they lengthened downplate.

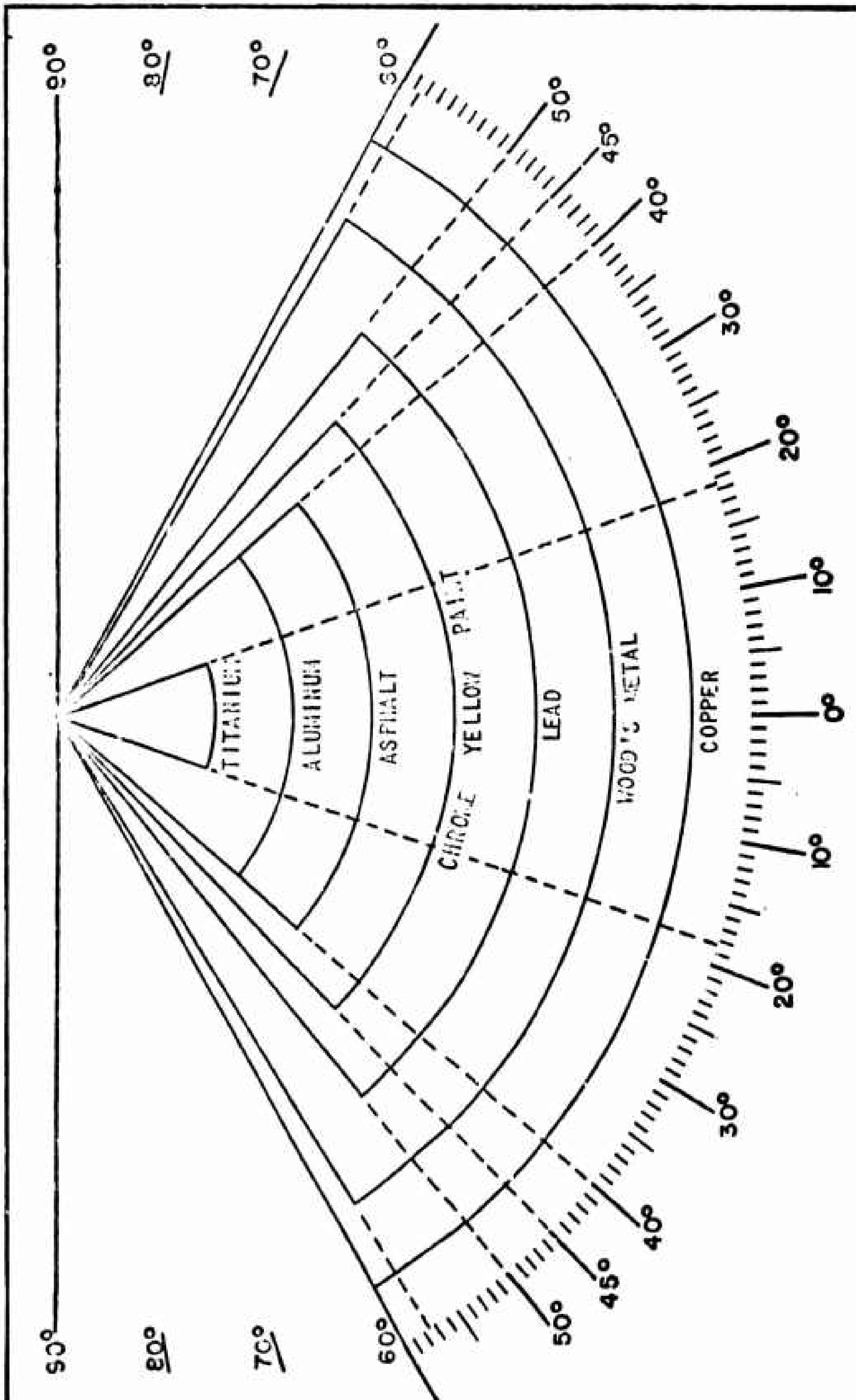
Wood's Metal dispersed in a pattern that was nearly geometrically perfect. Its zone included clearly defined and evenly spaced radial streaks which were about five inches in length. The pattern, however, was not deep-hued.

MATERIALS DISPERSION ON THE CYLINDRICAL TARGETS AT ZERO AND 45 DEGREES OBLIQUITY

The cylindrical targets at both zero and 45 degrees obliquity proved to be dispersion "witness targets," their surfaces showing deposits of materials and/or fragment perforations resulting from attack by solid and filler-type projectile materials dispersed from the armor at impact.

Zero Degrees Obliquity

The dispersions at zero degrees obliquity on most of the targets were freely distributed around the circumferential surfaces showing the marks of rebounding materials extending as far back as 10 inches, with heaviest concentration approximately 1-1/2 inches from the face of the armor.



DISPERSIONS OF EXPERIMENTAL PROJECTILES IMPACTED UPON ARMOR MATERIAL AT 45° OBLIQUITY

FIGURE 4

Of the various metallic dispersion patterns, the one made by Wood's Metal stood out most prominently. Its relatively wide zone showed many individual gray-colored cloud-like areas of vaporized metal, each characterized by numerous perforations and short tears. Included also were larger perforations and numerous small beads of Wood's Metal.

The titanium zone gave evidence of attack only by fractured projectile fragments, showing medium to small perforations and no vaporization.

The lead projectile deposited a comparatively small quantity of vaporized material, but left numerous marks of perforation ranging in size from large to small.

In the copper zone there were only scattered perforations of different sizes which were confined to a narrow circumferential band near the armor.

Except for a few tiny and barely visible beads, there was no trace of aluminum on the target. However, the pattern of perforation was very similar to that of copper.

Chrome yellow paint dispersed near the armor in a narrow zone of widely spaced patches, each of which was characterized by thinness of deposit. Also scattered about were small yellow bead-like particles.

The asphalt dispersion pattern was similar to that of chrome yellow paint, differing in the character of material deposited in and around the separated patches. These, in the asphalt pattern, were formed by the clustering of beads of material.

Forty-Five Degrees Obliquity

At 45 degrees obliquity, dispersions on the cylindrical targets were confined almost totally to the bottom sections, next to the armor, in zones up to 3 inches wide, with greatest concentration within 3/4 inch of the armor face. The variance in degrees of arc of these different zones is shown in Figure 4.

Evidence that a compact mass of disintegrated materials struck the target surface with considerable force at this obliquity was shown in the dense and/or deep-colored deposits of material surrounded by dispersed particles, the large perforations, and the jagged slashed-out areas.

Generally, the materials showed the same relative variance in character and extent of deposit on the cylinder as at zero degrees obliquity, except that a round hole approximately 0.510 inch in diameter (presumed to be a projectile mark) was found at midzone in each of the aluminum, titanium, and chrome yellow paint zones, and a 2-inch-wide crescent-shaped perforation was observable at a similar location in the copper zone.

Confirmation that any one projectile material dispersed in radial continuity from the point of impact on the armor to the surface of the cylindrical target was evidenced in the agreement of the angular degree measurements of dispersions on the armor, shown in Figure 4, with the degree of arc measurements on the cylindrical targets.

The proximity of each cylindrical target dispersion zone to the armor indicated that most of the dispersed material from every impact departed from the point of impact at an angle no greater than seven degrees to the surface of the armor in this velocity range.

RESULTS AND DISCUSSION

In evaluating the feasibility of a successful subcaliber spotting projectile, it should be taken into account that there are many variables to be considered in the design and application of a projectile of this type, unless the potential of the follow-up or major projectile is devastating. Some of the most noteworthy of the variables in spotting rounds would be: shots that are improperly aimed could result in near misses; projectiles that have excessive angles of impact (above 15 degrees); projectiles that do not behave uniformly upon impact (fracture or deformation); projectiles that may not fracture at maximum ranges; and projectiles intended to penetrate or partially penetrate the target upon impact, because this latter method would become ineffective at either short or extended ranges. Also there is the ever-present problem of the sudden shifting of the target.

There are other factors of prime importance to be considered, for example: the natural deceleration of small caliber projectiles as well as the susceptibility of the latter to the influence of wind; ballistic variations between spotting and service type projectiles due to differences in weight and shape of ogive.

Since projectile penetration, fracture and deformation are functional to terminal impact velocity as well as angle of attack, materials having low melting characteristics, such as fuzable alloys, lead and the like, will demonstrate superior qualities to materials such as steel or copper for possible use as spotting projectiles because they would be more effective throughout their flight.

There are many nonmetallic materials that may well be considered for this application, since it has been successfully demonstrated in this series of ballistic impact evaluations that both asphalt and oxide-based paints are worthy of consideration. Certain plastic compounds, especially thermoplastic types, would naturally prove highly satisfactory, for example, those plastic compounds having metallic suspensions. Also, some physical or chemical agent added to any of the above named materials could promote reflectiveness, luminosity or traceability.

Particularly significant to further testing in the development of a spotting shot is the annular type of area referred to in *Deposits of Metallic and Nonmetallic Filler Materials at Zero Degrees Obliquity*. These areas which were gouged out of the armor by the round chisel-like leading edges of the nose cavity projectile ogives proved highly receptive to the dispersed material.

In comparing the differences in impact dispersions at zero and 45 degrees incidence, it is noticeable that low-melting materials will disperse over a greater area at target obliquities than those materials having higher melting points, such as copper and steel. However, in studying the various zones it was noted that the amount of material deposited was negligible in all instances, ranging from a fraction of 1% for hard materials to approximately 1% for lead, asphalt, and chrome yellow paint.

CONCLUSIONS

The following conclusions have been reached as a result of this investigation:

1. That materials having low melting characteristics would be superior for fabrication of spotting round projectiles.

2. That it is difficult to obtain a predictable effectiveness in a spotting round because of the wide lateral dispersions at both zero and 45 degrees incidence.

3. That there are difficulties in developing a suitable spotting round which require added study.

RECOMMENDATIONS

1. Additional investigations should be conducted of ammunition having the spotting material at other locations; i.e., the middle or rear of the shot.

2. The subsequent studies should include metallic powder filler materials in the plastic component of the spotting rounds in order to define more effectively the dispersion of the solid and fluid components of the material.

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Report No. WAL TR 160.73/1, Jan 1960, 14 pp - table - illus, OO Proj TB3-1224, DA Proj 503-04-004, Unclassified Report

Exploratory ballistics impact tests have been made in which 0.510-inch-diameter scale model projectiles were fired at steel armor material at zero and 45 degrees obliquity. The projectiles were prepared from several types of metals, and also with a variety of filler materials included in their nose sections.

Observations of the terminal impact effect has been accomplished by comparing the zone of impact upon the target and the fragment dispersion upon a paper target completely surrounding the armor material.

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